Constellation-X
Facility Science Team Meeting
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Constellation-X Science Panel

Plasma Diagnostics and Atomic Astrophysics

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Panel Members

Nancy Brickhouse, Chair (CfA)
Greg Brown (Lawrence Livermore National Lab)
Li Ji (MIT)
Vinay Kashyap (CfA)
Masao Sako (U. Penn)
Wilt Sanders (NASA HQ)
Daniel Savin (Columbia U.)
Dave Schultz (Oak Ridge National Lab)
Randall Smith, Facilitator (NASA/GSFC)
Wayne Waldron (Eureka)
Brad Wargelin (CfA)

Panel Goals

- Develop prioritized “to do” list focused on Con-X science
  - Atomic theory
  - Atomic measurements
  - Plasma experiments
  - Astrophysics models
- Maintain long term focus
- Provide information and feedback to the other science panels
- Solicit inputs from the other science panels
- Develop an approach that parallels how the other panels are working

Decadal Survey

- AAS Working Group on Laboratory Astrophysics
  - Established May 2007
  - 12 members (incl. Brickhouse and Savin)
  - Broad (sub-mm to X-ray, nuclear physics, plasma physics, & chemistry)
  - Will sponsor 3 day session at 2008 summer AAS
  - Will participate in decadal survey
- NASA APRA program vs mission-specific programs

Organizing Schemes

- The shopping list
- Diagnostics approach

  Case: Ne IX G-ratio
- Global models approach

  Case: Abundance studies
- Astrophysics-driven approach

  Case: Sensitivity testing

The Shopping List

- Collisional ionization rate coefficients
- Photoionization rate coefficients
- Radiative recombination rate coefficients
- Dielectronic recombination rate coefficients
- Collisional excitation rate coefficients
- Oscillator strengths
- Wavelengths
- All elements < Z=30
- All ionization states in X-ray regime
- Fluorescence yields
- Inner shell lines
- Molecular/ solid absorption cross sections
- Charge exchange rate coefficients
- Comprehensive spectral models

PRO: Comprehensive

CON: Time consuming, shopping not popular with review panels

Diagnostics Approach

- **Hydrogen-like Lyman series**
- **Helium-like triplets**
- **Fe XVII “3C”/ “3D”**

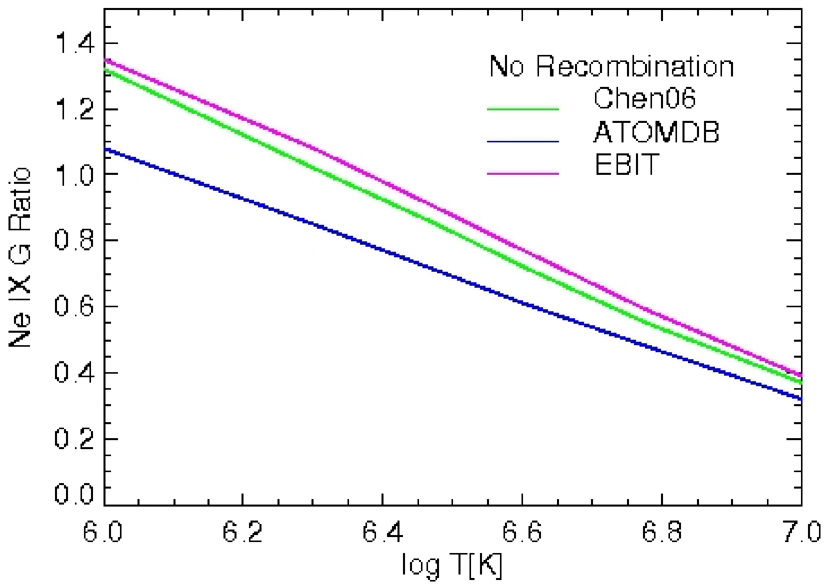
- **Atomic theory is capable of reaching 5 to 10% accuracy for selected line ratios.**
- **Atomic experimental verification is crucial.**
- **Systematic errors from experiments can be ~7 to 10%.**
- **Close collaboration between theory and experiment needed.**

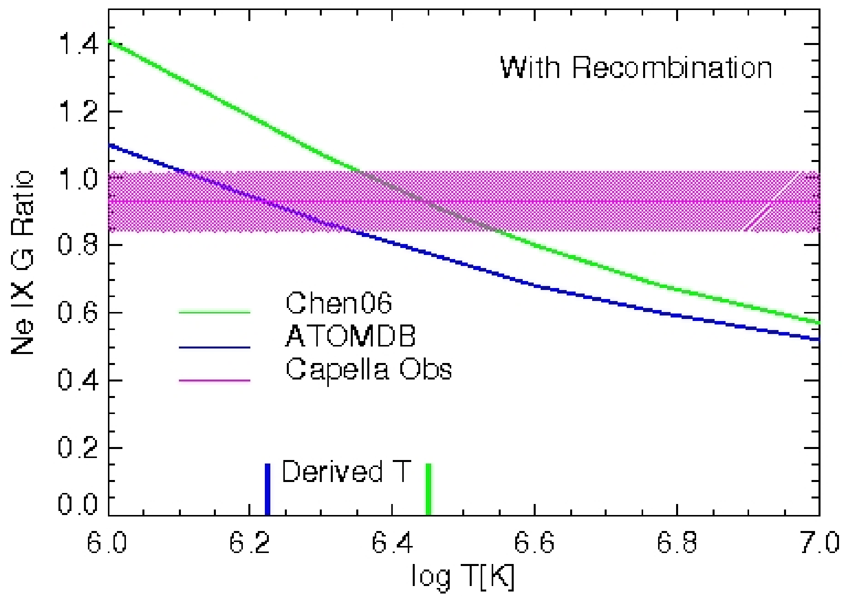
PRO: Produce reliable diagnostics for standard cases (e.g. ionization equilibrium) to test against.

CON: Resource-intensive, can only be used for most important data

Ne IX G-ratio
Theory and Experiment

New calculations (Chen et al. 2006, PRA)





G-ratio agrees with LLNL EBIT measurements of Wargelin (PhD Thesis 1993)

Derived T from Capella in better agreement (Smith et al. in prep)

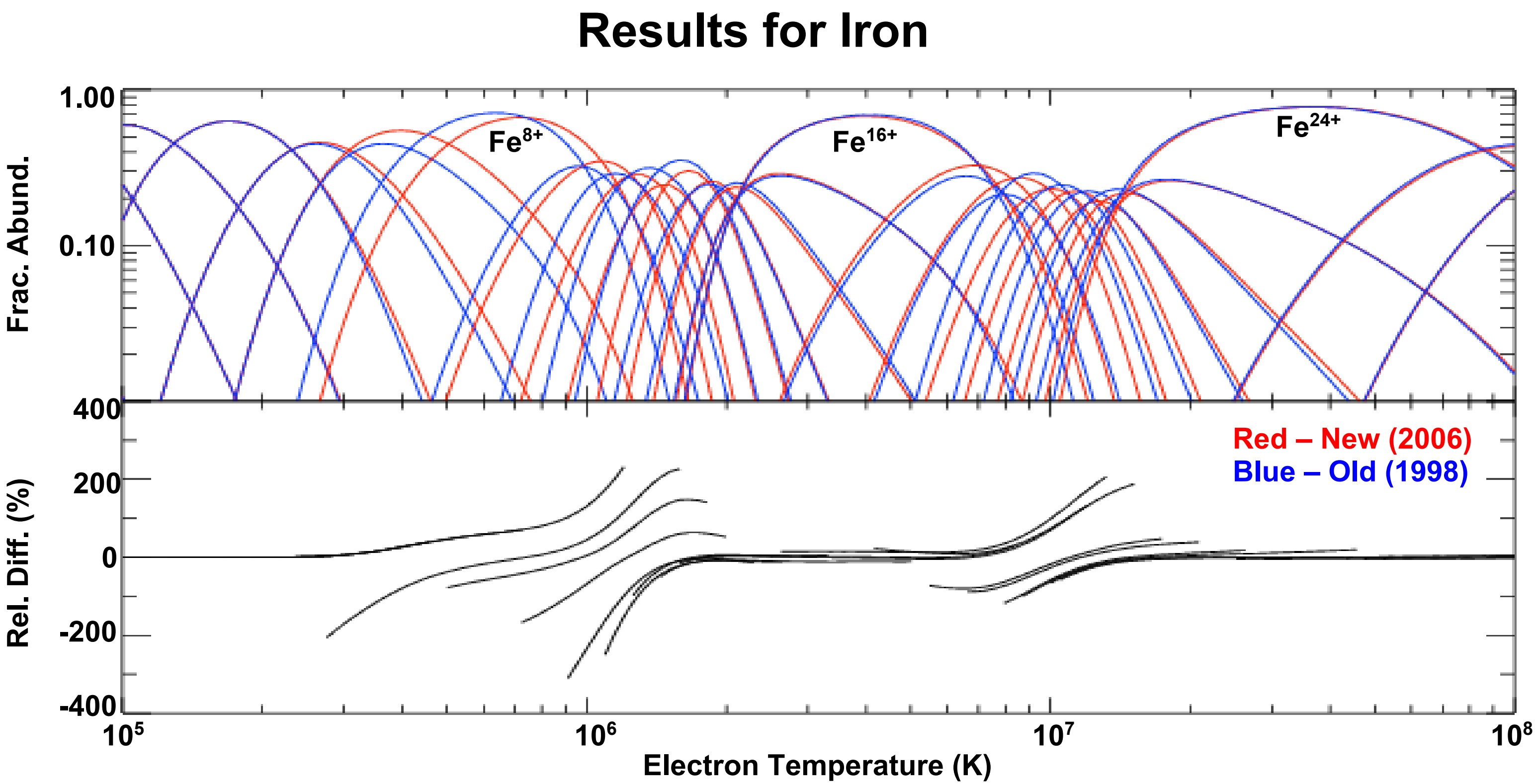
Global Models Approach

- Emphasizes completeness of spectral features (rather than accuracy)
- More robust than a few line ratios
- Requires treatment of systematic uncertainties (but this is hard, no clear agreement on how to simplify this)
- Helps eliminate blending worries

- Most rates 20 to 50% accurate
- Plasma experiments with spectroscopy
- Useful (maybe necessary?) for abundance determinations

- PRO: Uses all the observational data
- CON: Hard to define generically when the models are good enough

Determining Elemental Abundances: charge state balance and excitation



Bryans et al. 2007

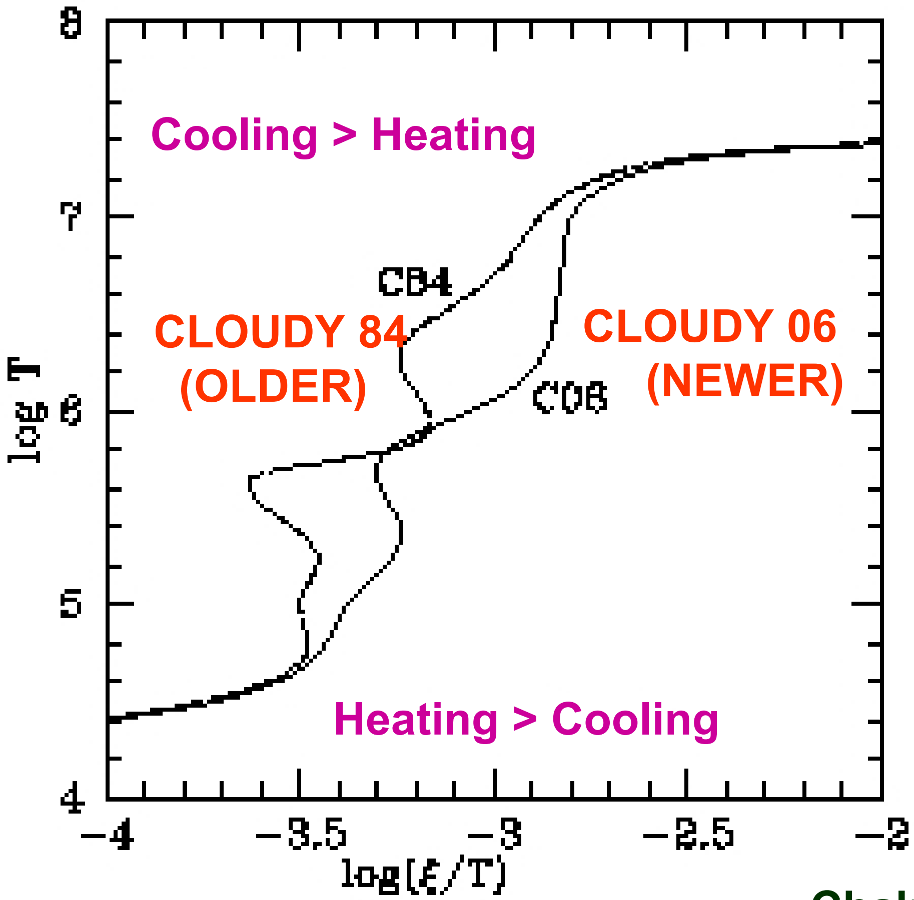
Astrophysics-Driven Approach

- Use observational goals to determine priorities
- Focus on key science
- Go beyond standard (over-simplified?) models
  - Departures from ionization equilibrium
  - Non-Maxwellian electron energy distributions
  - Magnetic field effects
  - Optical depth effects
  - Mixed collisional and photoionization
  - Photoexcitation

PRO: This is the most effective way to set priorities.

CON: Tends to be ad hoc, case-by-case basis.

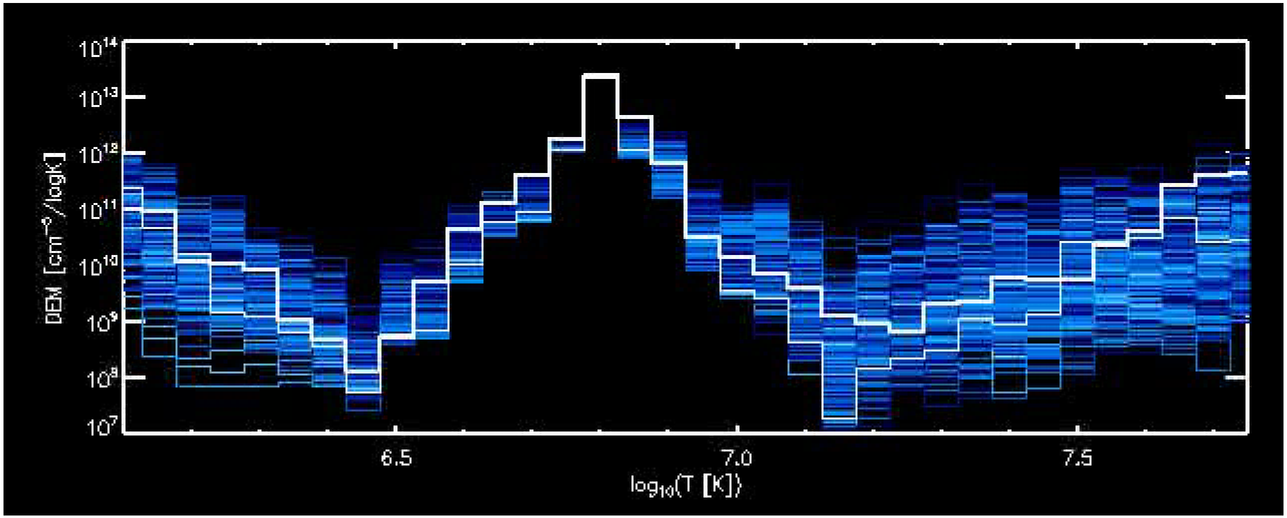
Effects of Atomic Data on Thermal Stability



Chakravorty et al. 2008

Sensitivity Testing Needs to Include Effects from Atomic Data

Capella DEM Models



Courtesy of Vinay Kashyap

Conclusions

- **Proper understanding of the atomic and plasma physics is required to understand the data from celestial sources.**
- **This requires controlled experiments and complete, detailed theory, which in turn requires resources and time.**
- **Stable funding, in particular for experimental groups with large infrastructure, needs to be in place. Do we have the proper facilities?**
- **Problems with the current models are currently preventing full use of current observations.**
- **Planning for the future requires that we first identify areas of greatest uncertainty, highest science priority, and means for improvement.**